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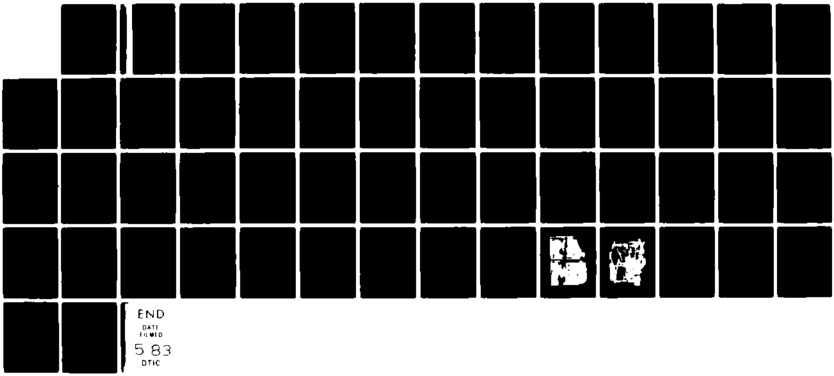

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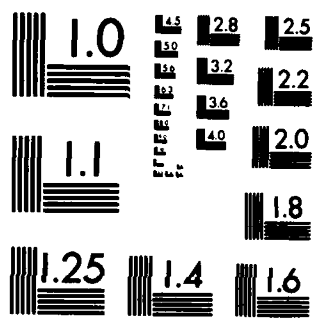

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DEPARTMENT OF DEFENCE SUPPORT

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Structures Technical Memorandum 349

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GROUND CALIBRATION OF A STRAIN-GAUGED CT-4A AIRCRAFT (1980)

by R. P. CAREY

SUMMARY

A CT-4A flight test aircraft has been strain-gauged and subjected to various ground calibration loadings including wing bending, wing torque, tailplane bending, and fin bending.

Results of regression analyses on the strain/load data are presented and compared with previous calibrations.

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CONTENTS

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1. INTRODUCTION

A series of ground calibrations has been performed on a CT-4A Airtrainer to determine appropriate strain/load factors to be applied in the interpretation of strain data from flight tests. The first calibration[1] in 1977 was intended to calibrate the structure before the flight tests. However, as the main flight testing was delayed, the ground calibrations were repeated in 1979[2] just before the main flight tests actually did proceed. A third set of calibrations in 1980 followed the flight tests and is the subject of this memorandum. The report also covers some calibracions that were performed in 1981 on a flight test tailplane that missed the 1980 calibrations, and a tailplane destined for fatigue testing.

2. AIRCRAFT CONFIGURATION

The most notable difference in status of the test aircraft (designated A19-031) between the 1979 and 1980 calibrations was a change of tailplane. During the period 1977 to 1981 the tailplanes were affected by a number of incidents and these have been itemised in Table 1.

The strain gauges (not on the tailplane) were unchanged from the 1979 calibration and their positions are shown in Figure 1 whilst more detailed drawings are listed in Reference 2. Gauge positions for the fatigue test tailplane are given in ARL drawing No. 53430-A1.

The main items removed from the aircraft for the calibration were the cockpit canopy, rudder, elevator and the nose undercarriage, which was replaced by a reaction structure.

3. LOADING METHODS

3.1 Wing Bending

The wing bending loading followed the procedure used on earlier calibrations[2] and is illustrated in Figure 2. In broad terms the incremental upwards loading was applied hydraulically and acted in opposition to fixed dead weight loading which corrected for the rig centre of gravity and also enabled nagative 'g' to be achieved. In terms of load factor the loading ranged from -1 g to +3 g.

In order to react the applied loading the fuselage was restrained by a dummy nose undercarriage and by a support/tie down for the floor structure behind the pilots' seats. These reaction points were retained throughout the calibrations.

3.2 Wing Torque Case 1

Briefly, the Case 1 Torque loading started from a 1 g pure bending state, with respect to the main spar datum, and dead weights were placed on forward or aft hangers to produce nose down or nose up torque. The torque-inducing dead weights were counter-balanced by upward hydraulic loading on the whiffletrees. This loading had the disadvantage that a change in bending moment distribution accompanied the torque change, particularly in the nose-up torque case[1]. Applied torques achieved at various wing stations are listed in Table 2. This was the only torque case calibrated before 1980, and has already been described in some detail.[2]

3.3 Wing Torque Case 2

The Wing Torque Case 2 was developed in 1980 to improve on the Case 1 Torque loading and calibration.

In this case equal and opposite torque distributions were applied to the two halves of the wing and were superimposed on a fixed bending moment distribution roughly corresponding to 1.15 g loading. The bending was produced by hydraulic jack loads of 5760N applied to the whiffletrees. No dead weights were used to produce bending.

The desired torque was achieved by loading through the clamping bolts at the ends of contour boards at Ribs 7, 9, 11 & 13. Equal dead weights were hung on the clamping bolts at one end of the contour boards whilst the bolts at the other end were equally loaded upwards by dead weights acting via a pulley and a simple whiffletree. The upwards dead weight loading was monitored by spring balances, one on the starboard and two on the port. The nominal torque inboard of Rib 7 was 1280 N.m. Calibration was initially done with nose up torque on the port and nose down on the starboard and that arrangement was later reversed. The loading is illustrated in Figure 3 and information on the torque distribution and applied bending loads is included in Tables 3 and 4.

3.4 Wing Torque Case 3 (with Bending)

The Wing Torque Case 3 was a combined bending and torque case to investigate whether wing bending loading had any influence on wing torque calibrations. The procedure was to apply wing bending load to +2 g level on each test run and then to superimpose torque loading in nose up and nose down directions on different runs.

The starting point for strain data collection was at -1 g load level and from that point wing bending load was increased to +2 g in one step using the same distribution and methods as for the pure bending calibration.

Torques were produced by two sets of vertical loads having the same distribution pattern but opposite direction. One set (upward) was obtained from an increase in whiffletree load at the main spar line. The other set (downward) was applied by deadweights and was arranged to have the same spanwise distribution as the whiffletree loading. The weights were placed on forward or aft weight hangers according to the torque direction required. Torque loading proceeded in two steps to 60% and 100% levels.

Details of the loads and the torque distributions are given in Table 5.

3.5 Tailplane, Fin, and Control Stick

The tailplane calibration load was applied by dead weight acting symmetrically on the outer elevator pivot and the levels were monitored by two spring balances.

The fin calibration loads were applied at the upper rudder hinge, also by dead weight acting through a pulley.

The control stick loading system used a turnbuckle and spring balance in series.

More detailed descriptions of these systems are contained in Ref. 2.

4. CALIBRATION LOADINGS

The ground calibrations done in 1980 have been summarised in Table 6. In general two preliminary loadings were carried out to condition the structure prior to a series of three calibration loadings.

As the first set of wing bending calibrations had some points of difference in result from the 1979 calibrations, a further calibration was done a week later as an additional check.

The Case 1 Wing Torque calibration was done with alternately nose up torque and nose down torque through the series of three calibrations.

The Case 2 Torque calibration was done three times with nose up torque on the port wing before changing the configuration to nose up starboard for the remaining three loadings.

The Case 3 Torque was rather limited. The number of preliminary runs was reduced from two to one and the number of calibration loadings was reduced from three to two. In addition the loading intervals were limited to one bending increment and two torque increments. The nose-up torque calibrations were completed first, followed by nose-down torque. Owing to a loading problem during the bending increment of the second nose-down loading, increments from a shortened third run (bending only) were substituted.

The 1980 tailplane calibrations were done on the tailplane recently fitted to the flight test aircraft. Loadings in both directions were completed without changing the strain gauge datums and the series of down loading calibrations was completed before the upwards loadings. In August 1981 calibrations were done in the same way on the possibly damaged tailplane which had been involved in most of the flight testing. At that time calibration was also done on the fatigue test tailplane. Both of these calibrations used the fatigue test airframe for support.

The fin calibrations were also done without changing strain datums. All loadings on the fin in the port direction were completed before proceeding to starboard direction loadings.

5. DATA TREATMENT

5.1 Data Collection

Data from strain gauges were recorded on magnetic tape by the LEACH MTR 2400 flight recorder which had been installed in the cockpit for the flight tests.

Data from the 1981 tailplane tests was collected using Hottinger strain-measuring instruments.

5.2 Data Processing

Linear regressions against load were fitted for the outputs of all strain gauges for individual loading runs and then groups of loading runs.

The regressions for wing bending calibrations covered the complete load range from -1 g to +3 g, firstly on a run by run basis and then grouping the runs performed on each day. A zero load (zero Newton) strain datum for this case was derived by interpolation between the adjacent data points, as strains were not measured at zero load. Grouped regressions were made relative to the reference zero from the first loading of each group.

Data from tailplane calibrations was put through regression analyses which grouped upward and downward loadings separately. The two slopes were then averaged to obtain a single value for each gauge. The regression intercepts from the upward and downward directions were combined to show the separation between the regression lines for the two loading directions.

Likewise regressions were done on the fin data from port and starboard loadings separately. Again slopes and intercepts from the two loading directions were combined as for the tailplane.

Grouped regressions for both tailplane and fin were made relative to the mean of the initial zeros from all the runs in both loading directions.

Regression slopes for the Case 1 Torque calibrations were obtained for the last two loading runs of each set, and averaged prior to making corrections for bending. Nominal loads were used.

The analysis of Case 2 Torque calibrations allowed for actual loads indicated by spring balance readings. In the case of grouped regressions the reference zero from the first loading was used for each group.

In the analysis of the Case 3 Torque calibration data, a weighted mean was taken of the mean strain differences for 60% and 100% load as follows:

Weighted Mean Strain for 100% torque

= (Mean Strain at 100% + 0.6 x Mean Strain at 60% Torque) / 1.36

The mean strains were the average values from the two loadings.

5.3 Sign Conventions

The convention for forces was that upwards, aft, and starboard applied forces were positive. Nose-down Torques on the wing have been taken as positive.

The relationship between the signs of strain bridge outputs and the sense of structural distortion is not readily determinable except in the obvious cases such as the bending bridges on the wing main spar. Also the gauge bridge signals have sometimes been reversed by wiring changes between calibrations so no attempt should be made to relate signs to the direction of distortion. In strain computations the following form has been consistently used:-

$$\text{Strain} = (\text{Reading at Load} - \text{Reference Value}) \times \frac{\text{Strain Equivalent (+ve)}}{\text{Calibration Step (+ve)}}$$

This convention differs from that used in reporting the 1977 and 1979 ground calibrations. The change has been made to comply with the convention used in analysing flight tests.

6. RESULTS

6.1 Results of 1980 and 1981 Calibrations

The results of regression analyses have been given in the form of gradients of the regression lines and intercepts of the regression lines on the strain axis (where available).

The regression gradients for various loading cases are given as follows:

Table 7 - Wing Bending

Tables 8, 9, 10 - Wing Torque Cases 1, 2, & 3

Table 11 - Substitute Tailplane

Table 12 - Main Flight Test Tailplane

Table 13 - Fatigue Test Tailplane

Table 14 - Fin

Table 15 - Control Stick

Intercepts on the strain axes are given as follows:

Table 12 - FLight Test Tailplane

Table 13 - Fatigue Test Tailplane

Table 16 - Wing Bending

Table 17 - Wing Torque Case 2

Table 18 - Substitute Tailplane

Table 19 - Fin.

6.2 Comparison of 1980 and 1981 Calibrations with Earlier Calibrations

Comparisons have been made between the gradients determined during calibrations in 1977, 1979, and 1980. The comparisons can be found in Table 20 (wing bending), Table 21 (tailplane), and Table 23 (fin). These tables also show the range of variation in the gradient over three years as a percentage of the mean. The range has also been given approximately in strain terms.

Table 22 compares the strain/load slopes from the fatigue test tailplane calibration with slopes from flight test tailplanes. Upward and downward loadings have been separated.

6.3 Comparison of Torque Calibrations

In Table 24 the data from the three wing torque cases has been compared in terms of strain per local torque. Torques at the particular spanwise positions of the gauges have been used in view of the variation in torque distributions from case to case. 1977 and 1980 Case 1 Torque calibrations have been included separately.

7. CENTRE SECTION STRAIN INVESTIGATION

In view of the very significant changes in calibration slopes from gauge 12BE on the main spar centre section, a more detailed investigation was undertaken.

At various stages of the investigation five additional gauges were applied to the main spar as detailed in Table 25. Gauges 62CE and 62TE were located between the fuselage sidewall and the wing rootrib, approximately 50mm outboard of the problem gauge, 12BE. Gauges 64CE and 64TE were a little inboard of 12BE and Gauge 60TE was 275mm inboard of it. Gauge 60TE was not matched on the upper spar cap.

As a further test, gauge 12BE was separated into four component gauges, two on the upper cap and two on the lower cap.

In a series of bending tests the usual load range -1 g to +3 g was applied. Results of the loadings are given in Table 25 in the form of strain per unit load at the various gauge positions.

The separation of gauge 12BE into component gauges showed that one upper boom gauge was producing less than half the output of the other. When allowance was made for the deficiency the average bending strain would be close to the value predicted by simple bending theory and higher than the original strain per unit load recorded in 1977. The agreement with simple bending theory is improved by a small correction for low slung wing pickups (see note Table 25). The history of reponses from gauge 12BE indicates that slow debonding began not long after the gauges were fitted. It should be remembered that this position was especially difficult to prepare.

8. DISCUSSION OF RESULTS

8.1 Centre Section Strains

(i) The investigation into the centre section strains shows conclusively that one gauge on the upper flange is reading extremely low, presumably due to debonding. This gauge is one of four forming a bending bridge.

(ii) When correction is made for the faulty gauge the bending strain agrees fairly well with simple bending theory, after a small allowance for the effect of low slung wing pickups.

(iii) The centre section upper boom strains are generally significantly larger than the lower boom values (see Table 25). It is thought that the difference occurs because the front and rear spar/fuselage pickups are below the neutral axis of the centre section spar, causing a net end load in the centre section and a reduction of the bending moment on the centre section resulting in much lower than otherwise expected strains in the lower boom of the centre section. This proposition has been supported qualitatively by the results of a finite element method (F.E.M.) analysis (see Appendix).

8.2 Wing Torque Loadings

(i) The Case 1 Nose-Up Torque values (Table 24) are generally out-of-step with the general trends shown by Case 2 and Case 3 Torque tests and the Case 1 Nose-Down Torque tests. This is probably due to the difficulty of correcting for the large amount of bending applied in that test and it is considered that those results should be ignored. Case 1 Nose-Down Torque calibrations also required some correction for bending.

(ii) Case 3 Torque tests are considered to be less reliable than Case 2 values because the quantity of data involved was much smaller. Case 3 torque results do not show any recognisable influence of bending loading when compared with the Case 2 tests.

(iii) The most promising indicators of torque are the shear gauges on the wing root rib web, 26SE and 30SE.

(iv) Five gauges 2BE, 4BE, 8BE, 32RB, and 20TE, which would be mainly influenced by wing bending, are also significantly influenced by wing torque (ref. Table 24).

8.3 Wing Bending Loadings

(i) Out of 20 gauges recorded during wing bending calibrations, 13 exhibited variation greater than 5% over the series of calibrations. It is considered that this is an indication of the inherent variability of the load paths through the airframe structure.

(ii) The large ratio of two between corresponding port and starboard front spar shear gauges, which was noted previously,[2] is still present. (see Table 20)

8.4 Tailplane and Fin Loadings

(i) There was enforced replacement of the strain gauges on the tailplane just before the main flight testing was performed. There was also a complete change of tailplane at a late stage of the flight testing following a flight overload. The associated wiring change would explain the change of sign of the response from the tailplane gauges (ref. Table 21).

(ii) Comparison of strain/load slopes from the fatigue tailplane and the various calibrations on flight tailplanes shows the range of values is generally around 20% for individual gauges (see Table 22). This figure has been obtained with upward and downward loadings treated separately. Averaging these would have reduced the range.

(iii) Gauge 36CE on the fatigue tailplane has shown a large difference in strain/load regression slope between upward and downward loadings. The values which are quoted in Table 13 are -.377 and -.714, a ratio of 1.9.

(iv) Over all the calibrations, the range of variation of the two fin gauge slopes increased to 6 and 7% with the inclusion of the latest results (Table 23), which agrees with the general performance of gauge positions elsewhere.

9. ACKNOWLEDGEMENTS

(i) The continued co-operation of Government Aircraft Factories personnel in preparing the calibration rigs and helping with test is much appreciated.

(ii) A valuable stress analysis contribution by V. Romeo (ARL) using the DISMAL package is also gratefully acknowledged.

REFERENCES

1.	Higgs, M.G.J.	Analysis of Ground Calibration Data from Strain Gauges Attached to the Airframe of CT4-A Airtrainer A19-031. ARL Structures Technical Memorandum 296 August 1979.
2.	Carey, R.P. and Costolloe, S.P.	Ground calibration of a Strain-gauged CT4-A Aircraft (1979). ARL Structures Technical Memorandum 330, April 1981.

APPENDIX 1

EFFECT OF LOW SLUNG WING PICKUPS

1. Difference of End Loads in Centre Section Booms

It is proposed that because the wing pickups are at a lower level than the neutral axis of the centre section, they transmit horizontal loads and cause an opposing reaction on the main spar centre section with effect on the centre section end loads particularly in the upper boom.

A finite element method analysis using the DISMAL package has confirmed that effect and in fact, the sum of the horizontal pickup reactions nearly matches the difference between centre section upper and lower booms loads, as will be shown below with reference to Figure 4:-

Sum of horizontal reactions at wing pickups = 2.91 + 3.64
= 6.55 kN.

Difference between upper and lower centre section boom loads
= 26.58 - 19.70
= 6.88 kN

2. Ration of Stresses and Strains at Centre Section

The ratio of stresses in upper and lower beams as derived from the F.E.M. analysis is in good agreement with the ratio of measured strains:-

Ratio of upper and lower boom stresses in centre section (From F.E.M. analysis) $= \dfrac{15.90 \text{ MPa (lower)}}{24.22 \text{ (upper boom)}}$
= .66

Ratio of measured strains in centre section booms (from 3 sound component gauges at station 12BE) $= \dfrac{1011 + 968}{2 \times 1458}$
= .68

3. Reduction in Bending Moment on Centre Section

The horizontal wing pickup loads (R_1 and R_3 in Figure 4) are balanced by an equal horizontal reaction of 6.55 kN at the centre section applied at an effective height 51.8mm below the mid depth. This results in the centre section bending moment being less than the wing root bending moment as follows;-

BM Reduction (Wing Root to Centre Section) = 6.55 kN x 51.8mm
= 339 N.m/g

% B.M. Reduction = $\dfrac{339}{4945} \times 100\% = 6.9\%$.

TABLE 1

TAILPLANES - SEQUENCE OF EVENTS

APPROX. DATES	EVENT	TAILPLANE	STRAIN GAUGE SET
MARCH 1977	GROUND CALIBRATION	ORIGINAL	ORIGINAL
MARCH 1977 to SEPT. 1979	MINOR FLIGHT TESTING	ORIGINAL	ORIGINAL
SEPT. 1979	GROUND CALIBRATION	ORIGINAL	ORIGINAL
AFTER SEPT. 1979	STRAIN GAUGES DAMAGED AND REPLACED	ORIGINAL	SECOND
PRE JUNE 1980	MAIN FLIGHT TESTING	ORIGINAL	SECOND
JUNE 1980	TAILPLANE DAMAGED IN FLIGHT AND REPLACED	SECOND	THIRD
PRE AUG. 1980	MINOR FLIGHT TESTING	SECOND	THIRD
AUG. 1980	GROUND CALIBRATION	SECOND	THIRD
AUG. 1981	CALIBRATION OF DAMAGED TAILPLANE ATTACHED TO FATIGUE TEST FUSELAGE	ORIGINAL	SECOND

TABLE 2

WING TORQUE CASE 1

APPLIED TORQUES

RIB NOS.	APPLIED TORQUES (N.m)	
	NOSE UP	NOSE DOWN
RIB 13 to RIB 11	0	170
RIB 11 to RIB 9	0	360
RIB 9 to RIB 7	-50	530
RIB 7 to RIB 5	-50	710
RIB 5 to RIB 3	-210	900
INBOARD of RIB 3	-1000	1290

CONVENTION: NOSE DOWN TORQUE +VE

TABLE 3

WING TORQUE CASE 2 LOADING

TORQUE LOADS

NOSE UP PORT SIDE*

RIB		TORQUE ARM (metre)	LOADS ON CLAMPING BOLTS	CUMULATIVE TORQUE INBOARD OF RIB (N.m)
13	PORT SIDE	1.251	222.4N EACH, UPWARD ON FORWARD BOLTS, DOWNWARD AFT.	- 280
11		1.372		- 580
9		1.502		- 920
7		1.628		- 1280
13	STAR BOARD SIDE	1.246	REVERSE OF ABOVE	280
11		1.369		580
9		1.499		910
7		1.628		1280

* NOSE UP STARBOARD CASE IS OPPOSITE OF ABOVE

CONVENTION: NOSE DOWN TORQUE +VE.

TABLE 4

WING TORQUE CASE 2 LOADING

BENDING LOADS

LOAD SOURCE	LOAD (N)
JACK LOAD VIA WHIFFLE TREE	5760 N UP
LESS	
WING WEIGHT	800 N DOWN
CONTOUR BOARD WEIGHT	1500 N DOWN
NETT LOAD PER SIDE	*3370 N UP

* THIS LOAD IS ROUGHLY EQUIVALENT TO LOAD FACTOR 1.15.

TABLE 5

WING TORQUE CASE 3 LOADING DETAILS

RIB NO.	TORQUE ARM (metre)	DEAD WEIGHT LOAD (N)	LOAD FROM WHIFFLETREE (N)	CUMULATIVE TORQUE INBOARD OF RIB (N.m)
NOSE UP TORQUE (100%)				
13	.315	556	549	- 170
11	.366	578	581	- 390
9	.404	667	671	- 660
7	.452	734	739	- 990
5	.493	556	547	- 1270
3	.440	500	506	- 1490
		(all at 60% Chord)		
NOSE DOWN TORQUE (100%)				
13	.312	As Above	As Above	170
11	.340			370
9	.380			620
7	.409			930
5	.445			1170
3	.696			1520

SIGN CONVENTION: NOSE DOWN TORQUE +VE.

TABLE 6

CT.4A 1980 CALIBRATION LOADINGS & LIMITED 1981 TAILPLANE CALIBRATIONS

TYPE OF CALIBRATION	TEST DATE	LOAD RANGE (NOMINAL)	NO. OF RUNS	STEPS	REMARKS
WING BENDING	27 AUG. 1980	-3240 N to +8455 N PER SIDE	3	0.5 g	-1g to +3g LOAD FACTOR
WING BENDING	4 SEPT. 1980		1	0.5 g	
WING TORQUE CASE 1	1 SEPT. 1980	0 to -1000N.m (NOSE-UP), then 0 to +1290N.m (NOSE DOWN)	3	20%	WING BENDING INITIALLY 1g BUT CHANGING ESPECIALLY DURING NOSE UP LOADING
WING TORQUE CASE 2	11 SEPT. 1980	0 to -1280N.m PORT 0 to 1280 N.m STARBOARD	3	20%	WING BENDING ≈ 1.15g CONST.
CASE 2	15 SEPT. 1980	REVERSE OF ABOVE	3	20%	WING BENDING ≈ 1.15g CONST.
WING TORQUE CASE 3	22 OCT. 1980 22 OCT. 1980	0 to -1490N.m (NOSE UP) 0 to +1520N.m (NOSE DOWN)	2 2	0%, 60%, 100%	WING BENDING FROM -1g TO +2g THEN TORQUE. 1 PRE-RUN
TAILPLANE FROM END OF FLIGHT TESTS	2 SEPT. 1980	0 to 556 N PER SIDE UP & DOWN	3	111.2N	STRAIN ZERO SETTINGS MAINTAINED
MAIN FLIGHT TEST TAILPLANE	12 AUG. 1981		3		
FATIGUE TEST TAILPLANE	20 AUG. 1981				
FIN PORT LOAD	3 SEPT 1980	0 to 445 N	3	89 N	STRAIN ZERO SETTINGS MAINTAINED
STARBOARD	3 SEPT 1980	0 to 445 N	3		
CONTROL STICK	29 AUG. 1980	0 to 445 N	3	89 N	

TABLE 7

WING BENDING CALIBRATION STRAIN/LOAD GRADIENTS

TEST DATES: 27 AUG. & 4 SEPT. 1980

GAUGE NO.	GAUGE LOCATION[2]	STRAIN ($x10^{-6}$) PER LOAD(N) PER SIDE		
		TEST ON: 27 AUGUST		4 SEPT.
		RUNS 3,4,5	RUNS 3,4,5 COMBINED	RUN 7
12BE	MAIN SPAR; 360 mm STARBOARD	.0847 .0846 .0849	.0848	.0849
10BE	MAIN SPAR; 1060 mm STARBOARD	- .0753 - .0752 - .0753	- .0753	- .0754
9BE	MAIN SPAR; 1060 mm TO PORT	- .0779 - .0776 - .0777	- .0777	- .0765
6BE	MAIN SPAR; 1820 mm TO STARBOARD	- .0649 - .0648 - .0646	- .0647	- .0647
5BE	MAIN SPAR; 1820 mm TO PORT	- .0656 - .0653 - .0653	- .0654	- .0652
2BE	MAIN SPAR; 2830 mm TO STARBOARD	- .0246 - .0244 - .0242	- .0244	- .0236
18CE	REAR SPAR; 1060 mm TO STARBOARD	.0046 .0045 .0045	.0045	.0044
20TE	REAR SPAR; 1060 mm TO STARBOARD	- .0365 - .0363 - .0363	- .0364	- .0356

TABLE 7 (CONT.)

GAUGE NO.	GAUGE LOCATION[2]	STRAIN ($x10^{-6}$) PER LOAD(N) PER SIDE		
		TEST ON: 27 AUGUST		4 SEPT.
		RUNS 3,4,5	RUNS 3,4,5 COMBINED	RUN 7
8BE	REAR SPAR; 1820 mm TO STARBOARD	- .0446 - .0445 - .0446	- .0446	- .0442
4BE	REAR SPAR; 2830 mm TO STARBOARD	- .0211 - .0211 - .0208	- .0210	- .0212
32RA	SKIN ROSETTE; 630 mm TO STARBOARD	- .0204 - .0207 - .0202	- .0205	- .0204
32RB	SKIN ROSETTE; 630 mm TO STARBOARD	- .0296 - .0295 - .0293	- .0295	- .0291
32RC	SKIN ROSETTE; 630 mm TO STARBOARD	.0260 .0263 .0262	.0262	.0271
21SE	WING FRONT SPAR SHEAR, 660 mm TO PORT	.0099 .0099 .0099	.0099	.0104
22SE	WING FRONT SPAR SHEAR, 660 mm TO STARBOARD	.0208 .0208 .0211	.0209	.0205
26SE	WING ROOT RIB SHEAR, 1800 mm AFT OF FUSE. DATUM, STBD. SIDE	.0331 .0332 .0331	.0332	.0339
30SE	WING ROOT RIB SHEAR 2840 mm AFT OF FUSE. DATUM, STBD. SIDE.	.0284 .0286 .0284	.0285	.0292

TABLE 7 (CONT.)

GAUGE NO.	GAUGE LOCATION[2]	STRAIN ($x10^{-6}$) PER LOAD(N) PER SIDE		
		TEST ON: 27 AUGUST		4 SEPT.
		RUNS 3,4,5	RUNS 3,4,5 COMBINED	RUN 7
24SE	WING REAR SPAR SHEAR; 610 mm TO STARBOARD	- .0111 - .0111 - .0111	- .0111	- .0111
27BE	PORT ROOT RIB BENDING; 2360 mm AFT OF FUSE. DATUM.	.0249 .0246 .0246	.0247	.0247
28BE	STBD. ROOT RIB BENDING; 2360 mm AFT OF FUSE. DATUM	.0291 .0292 .0290	.0291	.0302

1. MAXIMUM NOMINAL LOADS -3240 TO 8455 N PER SIDE (UP LOADS +VE)

2. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 8

WING TORQUE (CASE 1) CALIBRATION

STRAIN/TORQUE GRADIENTS

TEST DATE: 1 SEPT. 1980

GAUGE NO.	GAUGE LOCATION[3]	STRAIN ($x10^{-6}$) PER TORQUE[2] (N.m)	
		NOSE UP TORQUE	NOSE DOWN TORQUE
		RUNS 4&5 COMBINED	RUNS 4&5 COMBINED
12BE	MAIN SPAR; 360 mm STARBOARD	.022	.003
10BE	MAIN SPAR; 1060 mm STARBOARD	- .019	.000
9BE	MAIN SPAR; 1060 mm TO PORT	- .015	- .008
6BE	MAIN SPAR; 1820 mm TO STARBOARD	- .017	- .006
5BE	MAIN SPAR; 1820 mm TO PORT	- .010	- .006
2BE	MAIN SPAR; 2830 mm TO STARBOARD	- .005	- .002
18CE	REAR SPAR; 1060 mm TO STARBOARD	- .058	- .016
20TE	REAR SPAR; 1060 mm TO STARBOARD	.079	.056
8BE	REAR SPAR; 1820 mm TO STARBOARD	.016	.014
4BE	REAR SPAR; 2830 mm TO STARBOARD	- .003	.012

TABLE 8 (CONT.)

GAUGE NO.	GAUGE LOCATION[3]	STRAIN ($\times10^{-6}$) PER TORQUE[2] (N.m)	
		NOSE UP TORQUE	NOSE DOWN TORQUE
		RUNS 4&5 COMBINED	RUNS 4&5 COMBINED
32RA	SKIN ROSETTE; 630 mm TO STARBOARD	.023	.004
32RB	SKIN ROSETTE; 630 mm TO STARBOARD	- .010	- .037
32RC	SKIN ROSETTE; 630 mm TO STARBOARD	.045	.015
21SE	WING FRONT SPAR SHEAR 660 mm TO PORT	.010	.019
22SE	WING FRONT SPAR SHEAR 660 mm TO STARBOARD	.012	.028
26SE	WING ROOT RIB SHEAR 1800 mm AFT OF FUSE. DATUM, STBD. SIDE.	.006	- .039
30SE	WING ROOT RIB SHEAR 2840 mm AFT OF FUSE. DATUM, STBD. SIDE.	.097	.054
24SE	WING REAR SPAR SHEAR 610 mm TO STARBOARD	- .002	.002
27BE	PORT ROOT RIB BENDING 2360 mm AFT OF FUSE. DATUM	.029	.017
28BE	STBD. ROOT RIB BENDING; 2360 mm AFT OF FUSE. DATUM	.053	.018

1. NOSE UP TORQUE RANGE = 0 TO -1000 N.m AT WING ROOT.
   NOSE DOWN TORQUE RANGE = 0 TO 1290 N.m AT WING ROOT.
2. TORQUE AT WING ROOT.
3. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 9

WING TORQUE (CASE 2) CALIBRATION

STRAIN/TORQUE GRADIENTS

TEST DATES: 11 SEPT. & 15 SEPT. 1980

GAUGE NO.	GAUGE LOCATION[3]	STRAIN (X10^{-6})/TORQUE[2] (N.m)			
		NOSE UP PORT SIDE		NOSE UP STBD. SIDE	
		RUN 3 RUN 4 RUN 5	RUNS 3,4,5 COMBINED	RUN 8 RUN 9 RUN 10	RUNS 8,9,10 COMBINED
12BE	MAIN SPAR; 360 mm STARBOARD	- .007 - .008 - .008	- .007	- .006 - .003 - .002	- .003
10BE	MAIN SPAR; 1060 mm STARBOARD	.004 .004 .005	.004	.000 - .001 .000	- .000
9BE	MAIN SPAR; 1060 mm TO PORT	- .002 - .004 - .002	- .003	- .002 - .001 + .003	- .000
6BE	MAIN SPAR; 1820 mm TO STARBOARD	.004 .005 .004	.004	.014 .015 .014	.014
5BE	MAIN SPAR; 1820 mm TO PORT	.019 .017 .018	.018	- .003 - .002 - .001	- .002
2BE	MAIN SPAR; 2830 mm TO STARBOARD	.002 .002 .003	.003	.019 .018 .018	.018
18CE	REAR SPAR; 1060 mm TO STARBOARD	.002 .002 .002	.002	.009 .010 .010	.010
20TE	REAR SPAR; 1060 mm TO STARBOARD	.026 .026 .027	.026	- .021 - .021 - .023	- .021

TABLE 9 (CONT.)

GAUGE NO.	GAUGE LOCATION[3]	STRAIN ($X10^{-6}$)/$TORQUE^2$ (N.m)			
		NOSE UP PORT SIDE		NOSE UP STBD. SIDE	
		RUN 3 RUN 4 RUN 5	RUNS 3,4,5 COMBINED	RUN 8 RUN 9 RUN 10	RUNS 8,9,10 COMBINED
8BE	REAR SPAR; 1820 mm TO STARBOARD	.058 .059 .059	.059	.040 .041 .041	.041
4BE	REAR SPAR; 2830 mm TO STARBOARD	.018 .018 .016	.017	.032 .031 .031	.031
32RA	SKIN ROSETTE; 630 mm TO STARBOARD	.011 .011 .011	.011	.006 .004 .004	.005
32RB	SKIN ROSETTE; 630 mm TO STARBOARD	- .035 - .036 - .035	- .035	- .032 - .034 - .035	- .034
32RC	SKIN ROSETTE; 630 mm TO STARBOARD	.009 .009 .010	.009	.011 .011 .011	.011
21SE	WING FRONT SPAR SHEAR, 660 mm TO PORT	.013 .013 .014	.013	.013 .014 .013	.013
22SE	WING FRONT SPAR SHEAR, 660 mm TO STARBOARD	.013 .012 .013	.013	.010 .010 .011	.010
26SE	WING ROOT RIB SHEAR, 1800 mm AFT OF FUSE. DATUM, STBD. SIDE	- .038 - .038 - .039	- .038	- .036 - .036 - .036	- .036
30SE	WING ROOT RIB SHEAR, 2840 mm AFT OF FUSE. DATUM, STBD. SIDE	.059 .059 .060	.059	.059 .059 .059	.059

TABLE 9 (CONT.)

GAUGE NO.	GAUGE LOCATION[3]	STRAIN ($X10^{-6}$)/TORQUE[2] (N.m)			
		NOSE UP PORT SIDE		NOSE UP STBD. SIDE	
		RUN 3 RUN 4 RUN 5	RUNS 3,4,5 COMBINED	RUN 8 RUN 9 RUN 10	RUNS 8,9,10 COMBINED
24SE	WING REAR SPAR SHEAR, 610 mm TO STARBOARD	.006 .006 .006	.006	.004 .004 .004	.004
27BE	PORT ROOT RIB BENDING; 2360 mm AFT OF FUSE. DATUM	.011 .011 .011	.011	.013 .012 .012	.012
28BE	STBD. ROOT RIB BENDING; 2360 mm. AFT OF FUSE. DATUM	.016 .016 .016	.016	.017 .016 .016	.016

1. MAXIMUM NOMINAL TORQUES ±1280 N.m (NOSE UP AND NOSE DOWN).

2. TORQUE AT WING ROOT.

3. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 10

WING TORQUE (CASE 3) CALIBRATION (WITH BENDING)

STRAIN/TORQUE GRADIENTS

TEST DATE: 22 OCT. 1980

GAUGE NO.	GAUGE LOCATION[3]	BENDING ONLY STRAIN($X10^{-6}$) PER LOAD(N)	WEIGHTED MEAN STRAIN INCREMENT PER TORQUE[2] (N.m)	
			NOSE UP	NOSE DOWN
12BE	MAIN SPAR; 360 mm STARBOARD	.085	- .008	.002
10BE	MAIN SPAR; 1060 mm STARBOARD	- .076	.004	- .005
9BE	MAIN SPAR; 1060 mm TO PORT	- .078	.008	- .005
6BE	MAIN SPAR; 1820 mm TO STARBOARD	- .065	.017	.001
5BE	MAIN SPAR; 1820 mm TO PORT	- .067	.018	- .007
2BE	MAIN SPAR; 2830 mm TO STARBOARD	- .025	.003	- .003
18CE	REAR SPAR; 1060 mm TO STARBOARD	.004	.002	- .007
20TE	REAR SPAR; 1060 mm TO STARBOARD	.037	- .001	.015
8BE	REAR SPAR; 1820 mm TO STARBOARD	- .044	.011	.046
4BE	REAR SPAR; 2830 mm TO STARBOARD	- .021	.013	.005

TABLE 10 (CONT.)

GAUGE NO.	GAUGE LOCATION[3]	BENDING ONLY STRAIN ($X10^{-6}$) PER LOAD (N)	WEIGHTED MEAN STRAIN INCREMENT PER TORQUE[2] (N.m)	
			NOSE UP	NOSE DOWN
32RA	SKIN ROSETTE; 630 mm TO STARBOARD	- .022	.010	.011
32RB	SKIN ROSETTE; 630 mm TO STARBOARD	- .029	- .026	- .021
32RC	SKIN ROSETTE; 630 mm TO STARBOARD	.025	.012	.015
21SE	WING FRONT SPAR SHEAR, 660 mm TO PORT	.010	.019	.016
22SE	WING FRONT SPAR SHEAR, 660 mm TO STARBOARD	.020	.015	.016
26SE	WING ROOT RIB SHEAR, 1800 mm AFT OF FUSE. DATUM, STBD. SIDE	.034	- .030	- .031
30SE	WING ROOT RIB SHEAR, 2840 mm AFT OF FUSE. DATUM, STBD. SIDE	.029	.054	.049
24SE	WING REAR SPAR SHEAR, 610 mm TO STARBOARD	- .010	.002	.001
27BE	PORT ROOT RIB BENDING 2360 mm AFT OF FUSE. DATUM	.026	.004	.022
28BE	STBD. ROOT RIB BENDING; 2360 mm AFT OF FUSE. DATUM	.031	.018	.021

1. MAXIMUM TORQUES: -1490 N.m (NOSE UP)
   1520 N.m (NOSE DOWN)

2. TORQUE AT WING ROOT.

3. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 11

SUBSTITUTE TAILPLANE CALIBRATION LOADING

STRAIN/LOAD GRADIENTS

TEST DATE: 2 SEPT. 1980

GAUGE NO.	GAUGE LOCATION	STRAIN ($X10^{-6}$) PER LOAD(N) PER SIDE				
		DOWN LOADING		UP LOADING		AVERAGE OF UP & DOWN LOADINGS
		RUN 3 RUN 4 RUN 5	COMBINED 3,4,5	RUN 8 RUN 9 RUN 10	COMBINED 8,9,10	
36BE	TAILPLANE SPAR, 900 mm TO STARBOARD	.526 .524 .523	.522	.474 .471 .469	.479	.501
37BE	TAILPLANE SPAR, 200 mm TO PORT	.687 .689 .686	.688	.810 .807 .807	.814	.751
38BE	TAILPLANE SPAR, 200 mm TO STBD.	.651 .651 .650	.651	.745 .747 .742	.750	.701
51CE	FUSELAGE LOWER, PORT SIDE, 3110 mm AFT.	- .097 - .098 - .097	- .097	- .087 - .086 - .087	- .087	- .092
52CE	FUSELAGE LOWER, STBD. SIDE, 3110 mm AFT.	- .133 - .132 - .132	- .132	- .115 - .115 - .114	- .115	- .124
53TE	FUSELAGE UPPER PORT SIDE, 3330 mm AFT.	.159 .159 .159	.159	.156 .154 .155	.155	.157
54TE	FUSELAGE UPPER STBD. SIDE, 3330 mm AFT.	.147 .148 .148	.148	.142 .142 .142	.142	.145

1. MAXIMUM LOADS APPLIED = ±556N PER SIDE (UPWARDS & DOWNWARDS)
2. BE ≡ BENDING; CE ≡ COMPRESSION;
   TE ≡ TENSION; SE ≡ SHEAR
3. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 12

MAIN FLIGHT TEST TAILPLANE CALIBRATION LOADING

TEST DATE: 12 AUGUST 1981

GAUGE NO.	GRADIENT; STRAIN ($\times 10^{-6}$) PER LOAD(N) PER SIDE			STRAIN INTERCEPT ($\times 10^{-6}$)		
	RUN 3 / RUN 4	COMBINED DOWN LOADS	MEAN SLOPE FROM UP & DOWN LOADS	RUN 3 / RUN 4	COMBINED DOWN LOADS	UP LOAD INTERCEPT RELATIVE TO DOWN LOAD INTERCEPT
	RUN 7 / RUN 8	COMBINED UP LOADS		RUN 7 / RUN 8	COMBINED UP LOADS	
36BE	.515 / .515	.518	.496	7.12 / 7.74	8.61	16.07*
	.474 / .474	.474		- 7.58 / - 7.33	- 7.46	
37BE	.759 / .757	.764	.755	8.40 / 7.72	10.16	14.94*
	.744 / .745	.745		- 4.87 / - 4.70	- 4.78	
38BE	.786 / .787	.792	.768	5.53 / 5.19	7.44	6.29*
	.742 / .744	.743		.97 / 1.32	1.15	

THE INTERCEPTS, EXCEPT THOSE MARKED (*) ARE RELATIVE TO THE MEAN OF THE ZEROS AT THE START OF THE FOUR RUNS.

TABLE 13

CT4 FATIGUE TEST TAILPLANE CALIBRATION LOADING

TEST DATE: 21 AUGUST 1981

GAUGE NO.	RUN	GRADIENT; STRAIN ($X10^{-6}$) PER LOAD(N) PER SIDE	COMBINED DOWN LOADS (RUN 3, RUN 4) / COMBINED UP LOADS (RUN 7, RUN 8)	MEAN SLOPE FROM UP & DOWN LOADS	STRAIN INTERCEPT ($X10^{-6}$)	COMBINED DOWN LOADS (RUN 3, RUN 4) / COMBINED UP LOADS (RUN 7, RUN 8)	UP LOAD INTERCEPT RELATIVE TO DOWN LOAD INTERCEPT
36TE (LOWER SPAR BOOM)	RUN 3	.461	.463	.431	5.98	6.16	- 5.80*
	RUN 4	.462			3.61		
	RUN 7	.397	.398		.55	.36	
	RUN 8	.398			.23		
36CE (UPPER SPAR BOOM)	RUN 3	- .376	- .377	- .546	- .09	- .75	16.20*
	RUN 4	- .379			- 1.40		
	RUN 7	- .708	- .714		13.15	15.45	
	RUN 8	- .710			13.54		
37TE (LOWER SPAR BOOM)	RUN 3	.796	.805	.736	16.48	17.84	-18.62*
	RUN 4	.796			12.30		
	RUN 7	.665	.666		- .43	- .78	
	RUN 8	.663			.14		
37CE (UPPER SPAR BOOM)	RUN 3	- .638	- .639	- .687	- .83	- 1.96	12.67*
	RUN 4	- .635			- 1.22		
	RUN 7	- .729	- .735		9.40	10.71	
	RUN 8	- .729			9.52		
38TE (LOWER SPAR BOOM)	RUN 3	.679	.725	.678	4.13	10.85	-12.37*
	RUN 4	.758			12.94		
	RUN 7	.627	.631		- .06	- 1.52	
	RUN 8	.632			- 1.71		
38CE (UPPER SPAR BOOM)	RUN 3	- .649	- .653	- .695	- 2.88	- 4.09	14.18*
	RUN 4	- .650			- 2.85		
	RUN 7	- .731	- .737		8.69	10.09	
	RUN 8	- .731			7.25		

THE INTERCEPTS, EXCEPT THOSE MARKED(*) ARE RELATIVE TO THE MEAN OF THE ZEROS AT THE START OF THE FOUR RUNS

TABLE 14

FIN CALIBRATION LOADING

STRAIN/LOAD GRADIENTS

TEST DATE: 3 SEPT. 1980

GAUGE NO.	GAUGE LOCATION[2]	STRAIN ($X10^{-6}$) PER LOAD(N) PER SIDE				
		LOADING TO PORT		LOADING TO STBD.		AVERAGE OF PORT & STBD LOADINGS
		RUN 3 RUN 4 RUN 5	COMBINED 3,4,5	RUN 8 RUN 9 RUN 10	COMBINED 8,9,10	
33TE	FIN SPAR, PORT SIDE, 190 mm ABOVE F.R.L.	- .744 - .741 - .743	- .743	- .717 - .720 - .719	- .719	- .730
34TE	FIN SPAR, STBD. SIDE, 190 mm ABOVE F.R.L.	.724 .722 .728	.727	.740 .744 .739	.740	.734
51CE	FUSELAGE LONGERON, PORT, LOWER, 3110 mm AFT OF F.D.	- .040 - .040 - .041	- .040	- .040 - .041 - .041	- .040	- .040
52CE	FUSELAGE LONGERON, STBD., LOWER, 3110 mm AFT OF F.D.	.051 .051 .051	.051	.049 .051 .050	.050	.051
53TE	FUSELAGE LONGERON, UPPER, PORT, 3330 mm AFT OF F.D.	.014 .015 .015	.015	.015 .016 .015	.016	.016
54TE	FUSELAGE LONGERON, UPPER, STBD., 3330 mm AFT OF F.D.	- .018 - .018 - .018	- .019	- .020 - .018 - .018	- .019	- .019

1. MAXIMUM LOADS APPLIED = ± 445 N. (TO STBD. +VE)
(TO PORT -VE)

2. DISTANCE ABOVE FUSELAGE REFENCE LINE (F.R.L.) OR DISTANCE AFT OF FUSELAGE DATUM (F.D.).

TABLE 15

CONTROL STICK CALIBRATION

STRAIN/LOAD GRADIENT & ZERO LOAD INTERCEPTS

TEST DATE: 29 AUG. 1980

GAUGE NO.	GAUGE LOCATION	STRAIN ($X10^{-6}$) PER LOAD(N)*		STRAIN INTERCEPT AT ZERO LOAD ($X10^{-6}$)	
		RUN 3 RUN 4 RUN 5	RUNS 3,4,5 COMBINED	RUN 3 RUN 4 RUN 5	RUNS 3,4,5 COMBINED
55BE	BASE OF CONTROL STICK	2.62 2.62 2.64	2.61	- 45.1 - 42.5 - 50.5	- 46.1

* POSITIVE LOAD - PULLING AFT ON STICK.

TABLE 16

WING BENDING CALIBRATION

INTERCEPTS OF REGRESSION LINES ON STRAIN AXIS

GAUGE NO.	GAUGE LOCATION[2]	INTERCEPTS ($X10^{-6}$)	
		TESTS ON 27 AUG. 80	TEST ON 4 SEPT. 80
		RUNS 3,4,5 COMBINED	RUN 7
12BE	MAIN SPAR; 360 mm STARBOARD.	1.8	- .7
10BE	MAIN SPAR; 1060 mm STARBOARD.	- 4.6	- 4.4
9BE	MAIN SPAR; 1060 mm TO PORT.	- .7	- 9.3

TABLE 16 (CONT.)

GAUGE NO.	GAUGE LOCATION[2]	INTERCEPTS (X10^{-6})	
		TESTS ON 27 AUG. 80	TEST ON 4 SEPT. 80
		RUNS 3,4,5 COMBINED	RUN 7
21SE	WING FRONT SPAR SHEAR, 660 mm TO PORT.	1.7	- .5
22SE	WING FRONT SPAR SHEAR, 660 mm TO STARBOARD	5.5	8.9
26SE	WING ROOT RIB SHEAR 1800 mm AFT OF FUSE DATUM, STBD. SIDE	- 3.8	- 8.4
30SE	WING ROOT RIB SHEAR 2840 mm AFT OF FUSE DATUM, STBD. SIDE	3.5	- 3.1
24SE	WING REAR SPAR SHEAR, 610 mm TO STARBOARD	- 3.9	- 4.3
27BE	PORT ROOT RIB BENDING; 2360 mm AFT OF FUSE. DATUM	7.8	14.8
28BE	STBD. ROOT RIB BENDING; 2360 mm AFT OF FUSE. DATUM	13.1	7.0

1. TO OBTAIN STRAIN DATUMS AT ZERO LOAD (ZERO N) INTERPOLATION WAS PERFORMED ON THE NEAREST APPLICABLE DATA FROM THE FIRST LOADING.
2. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 16 (CONT.)

GAUGE NO.	GAUGE LOCATION[2]	INTERCEPTS ($x10^{-6}$)	
		TESTS ON 27 AUG. 80	TEST ON 4 SEPT. 80
		RUNS 3,4,5 COMBINED	RUN 7
6BE	MAIN SPAR; 1820 mm TO STARBOARD.	- 2.5	- 2.3
5BE	MAIN SPAR; 1820 mm TO PORT.	- 6.9	-10.0
2BE	MAIN SPAR; 2830 mm TO STARBOARD.	- 2.5	1.0
18CE	REAR SPAR; 1060 mm TO STARBOARD.	- 1.9	1.1
20TE	REAR SPAR; 1060 mm TO STARBOARD.	-11.8	- 6.7
8BE	REAR SPAR; 1820 mm TO STARBOARD.	- 6.6	-10.2
4BE	REAR SPAR; 2830 mm TO STARBOARD.	- 1.7	- .8
32RA	SKIN ROSETTE; 630 mm TO STAR-BOARD.	27.6	24.1
32RB	SKIN ROSETTE; 630 mm TO STAR-BOARD.	19.4	13.7
32RC	SKIN ROSETTE; 630 mm TO STAR-BOARD.	- 3.9	- 2.3

TABLE 17

WING TORQUE (CASE 2) CALIBRATION

INTERCEPTS OF REGRESSION LINES ON STRAIN AXIS

TEST DATES: 11 SEPT. & 15 SEPT. 1980

GAUGE NO.	GAUGE LOCATION*	INTERCEPTS ($\times 10^{-6}$)	
		NOSE UP TORQUE	NOSE DOWN TORQUE
		RUNS 3,4,5 COMBINED	RUNS 8,9,10 COMBINED
12BE	MAIN SPAR; 360 mm STARBOARD.	6.0	24.9
10BE	MAIN SPAR; 1060 mm STARBOARD	.2	2.6
9BE	MAIN SPAR; 1060 mm TO PORT	- .8	- 1.9
6BE	MAIN SPAR; 1820 mm TO STARBOARD	- .6	- 1.8
5BE	MAIN SPAR; 1820 mm TO PORT	- 4.6	- 6.7
2BE	MAIN SPAR; 2830 mm TO STARBOARD	- 2.3	- 3.5
18CE	REAR SPAR; 1060 mm TO STARBOARD	.6	3.5
20TE	REAR SPAR; 1060 mm TO STARBOARD	- 3.4	.1
8BE	REAR SPAR; 1820 mm TO STARBOARD	1.2	2.4
4BE	REAR SPAR; 2830 mm TO STARBOARD	1.8	.6

TABLE 17 (CONT.)

GAUGE NO.	GAUGE LOCATION*	INTERCEPTS ($X10^{-6}$)	
		NOSE UP TORQUE	NOSE DOWN TORQUE
		RUNS 3,4,5 COMBINED	RUNS 8,9,10 COMBINED
32RA	SKIN ROSETTE; 630 mm TO STARBOARD	- 1.1	- 4.1
32RB	SKIN ROSETTE; 630 mm TO STARBOARD	- 1.7	- 3.3
32RC	SKIN ROSETTE; 630 mm TO STARBOARD	1.7	- 1.3
21SE	WING FRONT SPAR SHEAR, 660 mm TO PORT	- .5	2.6
22SE	WING FRONT SPAR SHEAR, 660 mm TO STARBOARD	.6	10.7
26SE	WING ROOT RIB SHEAR, 1800 mm AFT OF FUSE. DATUM, STBD. SIDE	- .6	- 1.4
30SE	WING ROOT RIB SHEAR, 2840 mm AFT OF FUSE. DATUM, STBD. SIDE	1.4	3.5
24SE	WING REAR SPAR SHEAR, 610 mm TO STARBOARD	.1	- 1.2
27BE	PORT ROOT RIB BENDING, 2360 mm AFT OF FUSE. DATUM	1.8	8.2
28BE	STBD. ROOT RIB BENDING, 2360 mm AFT OF FUSE. DATUM	.5	- 1.0

* DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 18

SUBSTITUTE TAILPLANE CALIBRATION LOADING

INTERCEPTS OF REGRESSION LINE ON STRAIN AXIS

TEST DATE: 2 SEPT. 1980

GAUGE NO.	GAUGE LOCATION[3]	INTERCEPTS[2] ($x10^{-6}$)		
		DOWN LOADING	UP LOADING	UP LOADINGS RELATIVES TO DOWN LOADINGS
		RUN 3, RUN 4, RUN 5 COMBINED	RUN 8, RUN 9, RUN 10 COMBINED	
36BE	TAILPLANE SPAR, 900 mm TO STARBOARD	5.7	- 9.9	- 15.6
37BE	TAILPLANE SPAR, 200 mm TO PORT	.6	- 2.7	- 3.3
38BE	TAILPLANE SPAR, 200 mm TO STARBOARD	1.6	- 1.8	- 3.4
51CE	FUSELAGE LONGERON, LOWER PORT SIDE, 3110 mm AFT	- .2	.1	0.3
52CE	FUSELAGE LONGERON, LOWER STBD. SIDE, 3110 mm AFT	1.9	- 2.6	- 4.5
53TE	FUSELAGE LONGERON, UPPER PORT SIDE, 3330 mm AFT	- 3.2	3.5	6.7
54TE	FUSELAGE LONGERON, UPPER STBD. SIDE, 3330 mm AFT	- 3.2	3.3	6.5

1. MAXIMUM LOADS APPLIED = ± 556 N PER SIDE. (UPWARDS & DOWNWARDS)
2. INTERCEPTS ARE RELATIVE TO THE MEAN OF THE VALUES AT THE START OF 6 LOADINGS (INCLUDING UP & DOWN LOADINGS), EXCEPT THE LAST COLUMN.
3. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 19

FIN CALIBRATION LOADING

INTERCEPTS OF REGRESSION LINES ON STRAIN AXIS

TEST DATE: 3 SEPT. 1980

GAUGE NO.	GAUGE LOCATION[3]	INTERCEPTS[2] (X10^{-6})		
		LOADING TO PORT	LOADING TO STBD.	STBD. LOADINGS RELATIVE TO PORT LOADINGS
		RUN 3, RUN 4, RUN 5 COMBINED	RUN 8, RUN 9, RUN 10 COMBINED	
33TE	FIN SPAR, PORT SIDE, 190 mm ABOVE F.R.L.	10.7	- 11.1	- 21.8
34TE	FIN SPAR, STBD. SIDE, 190 mm ABOVE F.R.L.	- 20.1	22.2	42.3
51CE	FUSELAGE LONGERON, PORT, LOWER, 3110 mm AFT OF F.D.	2.6	3.4	.8
52CE	FUSELAGE LONGERON, STBD., LOWER, 3110 mm AFT OF F.D.	- .4	.7	1.1
53TE	FUSELAGE LONGERON, UPPER, PORT, 3330 mm AFT OF F.D.	- 1.0	.5	1.5
54TE	FUSELAGE LONGERON, UPPER, STBD., 3330 mm AFT OF F.D.	.1	- 1.1	- 1.2

NOTES 1. MAXIMUM LOADS APPLIED = ± 445 N. (TO STBD. +VE)
(TO PORT -VE)

2. INTERCEPTS ARE RELATIVE TO THE MEAN OF THE VALUES AT THE START OF 6 LOADINGS (INCLUDING STARBOARD & PORT DIRECTIONS), EXCEPT THE LAST COLUMN.

3. DISTANCE ABOVE FUSELAGE REFERENCE LINE (F.R.L.) OR AFT OF FUSELAGE DATUM (F.D.).

TABLE 20

COMPARISON OF WING BENDING CALIBRATIONS

STRAIN/LOAD GRADIENTS

TEST DATES: MARCH 1977, SEPT. 1979, AUG. 1980

GAUGE NO.	GAUGE LOCATION[2]	STRAIN ($X10^{-6}$) PER LOAD (N)			RANGE PERCENT	APPROX. RANGE[1] ($X10^{-6}$ STRAIN)
		MARCH 1977	SEPT. 1979	AUG. 1980		
12BE	MAIN SPAR; 360 mm TO STARBOARD	- .1023	.0876	.0848	19.1	205
10BE	MAIN SPAR; 1060 mm TO STARBOARD	- .0724	- .0742	- .0753	3.9	34
9BE	MAIN SPAR; 1060 mm TO PORT	- .0740	- .0754	- .0777	4.9	43
6BE	MAIN SPAR; 1820 mm TO STARBOARD	- .0616	- .0608	- .0647	6.3	46
5BE	MAIN SPAR; 1820 mm TO PORT	- .0628	- .0628	- .0654	4.1	30
2BE	MAIN SPAR; 2830 mm TO STARBOARD	- .0239	- .0228	- .0244	6.8	19
18CE	REAR SPAR; 1060 mm TO STARBOARD	.0052	.0031	.0045	49.2	25
20TE	REAR SPAR; 1060 mm TO STARBOARD	- .0344	- .0348	- .0364	5.7	23
8BE	REAR SPAR; 1820 mm TO STARBOARD	- .0420	- .0418	- .0446	6.5	33
4BE	REAR SPAR; 2830 mm TO STARBOARD	- .0203	- .0204	- .0210	3.4	8

TABLE 20 (CONT.)

GAUGE NO.	GAUGE LOCATION[2]	STRAIN ($\times 10^{-6}$) PER LOAD (N)			RANGE PERCENT	APPROX. RANGE[1] ($\times 10^{-6}$ STRAIN)
		MARCH 1977	SEPT. 1979	AUG. 1980		
32RA	SKIN ROSETTE: 630 mm TO STARBOARD	- .0270	- .0243	- .0205	27.2	76
32RB	SKIN ROSETTE; 630 mm TO STARBOARD	- .0299	- .0302	- .0295	2.3	8
32RC	SKIN ROSETTE; 630 mm TO STARBOARD	.0286	.0288	.0262	9.3	30
21SE	WING FRONT SPAR SHEAR; 660 mm TO PORT SIDE	.0110	.0103	.0099	10.6	13
22SE	WING FRONT SPAR SHEAR; 660 mm TO STBD. SIDE	.0202	.0204	.0209	3.4	8
26SE	WING ROOT RIB SHEAR; 1800 mm AFT OF FUSE. DATUM, STBD. SIDE	.0321	.0336	.0332	4.6	18
30SE	WING ROOT RIB SHEAR; 2840 mm AFT OF FUSE. DATUM, STBD. SIDE	.0266	.0287	.0285	7.5	25
24SE	WING REAR SPAR SHEAR; 610 mm TO STARBOARD SIDE	.0100	.0115	.0111	13.8	18
27BE	PORT ROOT RIB BENDING; 2360 mm AFT OF FUSELAGE DATUM	.0259	.0237	.0247	8.9	26
28BE	STBD. ROOT RIB BENDING; 2360 mm AFT OF FUSELAGE DATUM	.0310	.0288	.0291	7.4	26

1. THE APPROXIMATE RANGE (MICROSTRAIN) IS THE PRODUCT OF THE RANGE OF SLOPES AND THE LOADING RANGE, AND IS INTENDED TO SHOW THE VARIATION IN TERMS OF STRAIN.

2. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 21

COMPARISON OF VARIOUS CALIBRATIONS OF TAILPLANES

STRAIN/LOAD GRADIENTS

TEST DATES: 1977, 1979, 1980

GAUGE NO.	GAUGE LOCATION[2]	STRAIN ($X10^{-6}$) PER LOAD(N) (AVERAGE OF UP & DOWN LOADINGS)			RANGE PERCENT	APPROX. RANGE[1] ($X10^{-6}$ STRAIN)
		MARCH 1977	SEPT. 1979	SEPT. 1980		
36BE	TAILPLANE SPAR 900 mm TO STARBOARD	- .479	- .492	.501	4.5	24
37BE	TAILPLANE SPAR 200 mm TO PORT	- .752	- .694	.751	7.9	64
38BE	TAILPLANE SPAR 200 mm TO STBD.	- .776	- .725	.701	10.2	83
51CE	FUSELAGE LOWER PORT, 3110 mm AFT.	- .094	- .085	- .092	10.0	10
52CE	FUSELAGE LOWER STBD, 3110 mm AFT.	- .107	- .104	- .124	17.9	22
53TE	FUSELAGE UPPER PORT, 3330 mm AFT.	.152	.154	.157	3.2	5
54TE	FUSELAGE UPPER STBD, 3330 mm AFT.	.159	.142	.145	11.4	19

1. THE APPROXIMATE RANGE (MICROSTRAIN) IS THE PRODUCT OF THE RANGE OF SLOPES AND THE LOADING RANGE, AND IS INTENDED TO SHOW THE VARIATION IN TERMS OF STRAIN. FOR TAILPLANE CALIBRATIONS THE LOAD RANGE BETWEEN EXTREME UPWARD & DOWNWARD LOADINGS WAS USED.

2. DISTANCE AFT OF FUSELAGE DATUM OR SPANWISE FROM CENTRELINE.

TABLE 22

FATIGUE TEST TAILPLANE & FLIGHT TEST TAILPLANES - COMPARISON OF SLOPES (STRAIN/LOAD) FROM VARIOUS CALIBRATIONS

GAUGE POSITION	LOAD DIRECTION	STRAIN ($X10^{-6}$) PER LOAD(N) PER SIDE					
		FLIGHT TEST TAILPLANES CALIBRATIONS AT DATES BELOW. (..BE GAUGES)				FATIGUE TEST TAILPLANE (MEAN OF ..TE,..CE GAUGES)	% RANGE OF SLOPE
		1977	1979	1980	1981		
36BE or {36CE 36TE	DOWN	.480	.521	.524	.518	.420	21
	UP	.478	.456	.471	.474	.556	21
37BE or {37CE 37TE	DOWN	.807	.672	.687	.763	.722	19
	UP	.696	.704	.808	.745	.701	15
38BE or {38CE 38TE	DOWN	.830	.708	.651	.792	.689	24
	UP	.720	.727	.745	.743	.684	8

UPWARD AND DOWNWARD LOADINGS ARE SEPARATED.

TABLE 23

COMPARISON OF FIN CALIBRATIONS

STRAIN/LOAD GRADIENTS

TEST DATES: 1977, 1979, 1980

GAUGE NO.	GAUGE LOCATION[2]	STRAIN ($\times 10^{-6}$) PER LOAD(N) (AVERAGE OF STBD.&PORT LOADINGS			RANGE PERCENT	APPROX. RANGE[1] ($\times 10^{-6}$ STRAIN)
		MARCH 1977	SEPT. 1979	AUG. SEPT. 1980		
33TE	FIN SPAR, PORT SIDE 190 mm ABOVE F.R.L.	- .776	- .740	- .730	6.1	41
34TE	FIN SPAR, STBD. SIDE 190 mm ABOVE F.R.L.	.787	.739	.734	7.0	47
51CE	FUSELAGE LOWER PORT, 3110 mm AFT.	- .036	- .042	- .040	15.4	5
52CE	FUSELAGE LOWER STBD, 3110 mm AFT.	.042	.049	.051	19.1	8
53TE	FUSELAGE UPPER PORT, 3330 mm AFT.	.021	- .016	.016	27.8	4
54TE	FUSELAGE UPPER STBD, 3330 mm AFT.	- .020	.020	- .019	5.0	1

1. THE APPROXIMATE RANGE (MICROSTRAIN) IS THE PRODUCT OF THE RANGE OF SLOPES AND THE LOADING RANGE, AND IS INTENDED TO SHOW THE VARIATION IN TERMS OF STRAIN. FOR FIN CALIBRATIONS THE LOAD RANGE BETWEEN PORT AND STARBOARD LOADINGS WAS USED.

2. DISTANCE ABOVE FUSELAGE REFERENCE LINE (F.R.L.) OR AFT OF FUSELAGE DATUM.

TABLE 24

SUMMARY OF TORQUE CALIBRATION GRADIENTS RELATIVE TO LOCAL TORQUES

GAUGE NO.	STRAIN ($X10^{-6}$ PER LOCAL TORQUE (N.m)							
	NOSE DOWN TORQUE				NOSE UP TORQUE			
	CASE 1		CASE 2	CASE 3	CASE 1		CASE 2	CASE 3
	1977	1980	1980	1980	1977	1980	1980	1980
21SE	.016	.019	.013	.016	.008	.010	.013	.019
27BE	.017	.017	.012	.022	.026	.029	.011	.004
22SE	.023	.028	.013	.016	.010	.012	.010	.013
24SE	.006	.002	.006	.001	0	- .002	.004	.002
26SE	- .036	- .039	- .038	- .031	.011	.006	- .036	- .030
28BE	.023	.018	.016	.021	.044	.053	.016	.018
30SE	.051	.053	.059	.049	.091	.097	.059	.054
5BE	- .003	- .011	- .002	- .012	- .196	- .211	.018	.026
9BE	- .002	- .011	0	- .006	- .086	- .071	- .003	.010
2BE	.011	- .006	.006	- .011	-	-	.040	.010
4BE	.078	.044	.037	.021	-	-	.069	.052
6BE	- .001	- .011	.004	.002	- .261	- .367	.014	.026
8BE	.008	.026	.059	.076	- .261	- .346	.041	.016
10BE	.001	- .001	.005	- .006	- .100	- .092	0	.005
12BE	.004[1]	.003[1]	- .007	.002[1]	.008[1]	.022[1]	- .003	- .008[1]
18CE	- .022	- .022	.002	- .009	- .238	- .278	.010	.002
20TE	.031	.080	.026	.020	.229	.374	- .021	- .002
32RA	.001	.004	.011	.011	- .011	.023	.005	.010
32RB	- .026	- .037	- .035	- .021	- .027	- .010	- .034	- .026
32RC	.026	.016	.009	.015	.040	.044	.011	.012

1 WING ROOT TORQUE VALUE USED.

TABLE 25

GAUGES ON MAIN SPAR CENTRE SECTION

GAUGE NO.	DISTANCE FROM AIRCRAFT CENTRELINE	SPAR CAP	SURFACE OF SPAR CAP	TEST DATE	STRAIN ($X10^{-6}$) PER LOAD (N) PER SIDE	STRAIN PREDICTION (SIMPLE BENDING) $X10^{-6}/N$
12BE	501 mm	BOTH	INNER	17/9/80	.084	.110
60TE	226 mm	LOWER	OUTER	17/9/80	.092	.103
62TE 62CE	BETWEEN ROOT RIB & FUSELAGE 552 mm	LOWER UPPER	OUTER	17/9/80	.136 - .208	.127 - .140
12BE	501 mm	BOTH	INNER	16/10/80	.086	
64TE 64CE	448 mm 478 mm	LOWER UPPER	INNER	16/10/80	.091 - .122 } .106	
12BE 12BE	501 mm COMPONENT GAUGES	LOWER	INNER	20/10/80	.086 .083	.110
					} .086[1]	
12BE 12BE	501 mm COMPONENT GAUGES	UPPER	INNER	20/10/80	- .125 - .050	

NOTE 1. IF THE STRAIN/N = .050 WERE MODIFIED TO .125 IN LINE WITH THE ADJACENT GAUGE THE COMBINED BENDING STRAIN WOULD BE .105 AND THIS WOULD BE IN GOOD AGREEMENT CONSIDERING THAT THE SIMPLE BENDING APPROACH PROBABLY OVER-ESTIMATES THE MEAN BENDING STRAIN BY ABOUT 6.9% (SEE APPENDIX).

Notes:

BE:–	Bending bridge, combining tensile & compressive strains.
CE, TE:–	Separate compressive or tensile strains.
SE:–	Shear bridge
RA, RB, RC:–	Rosette

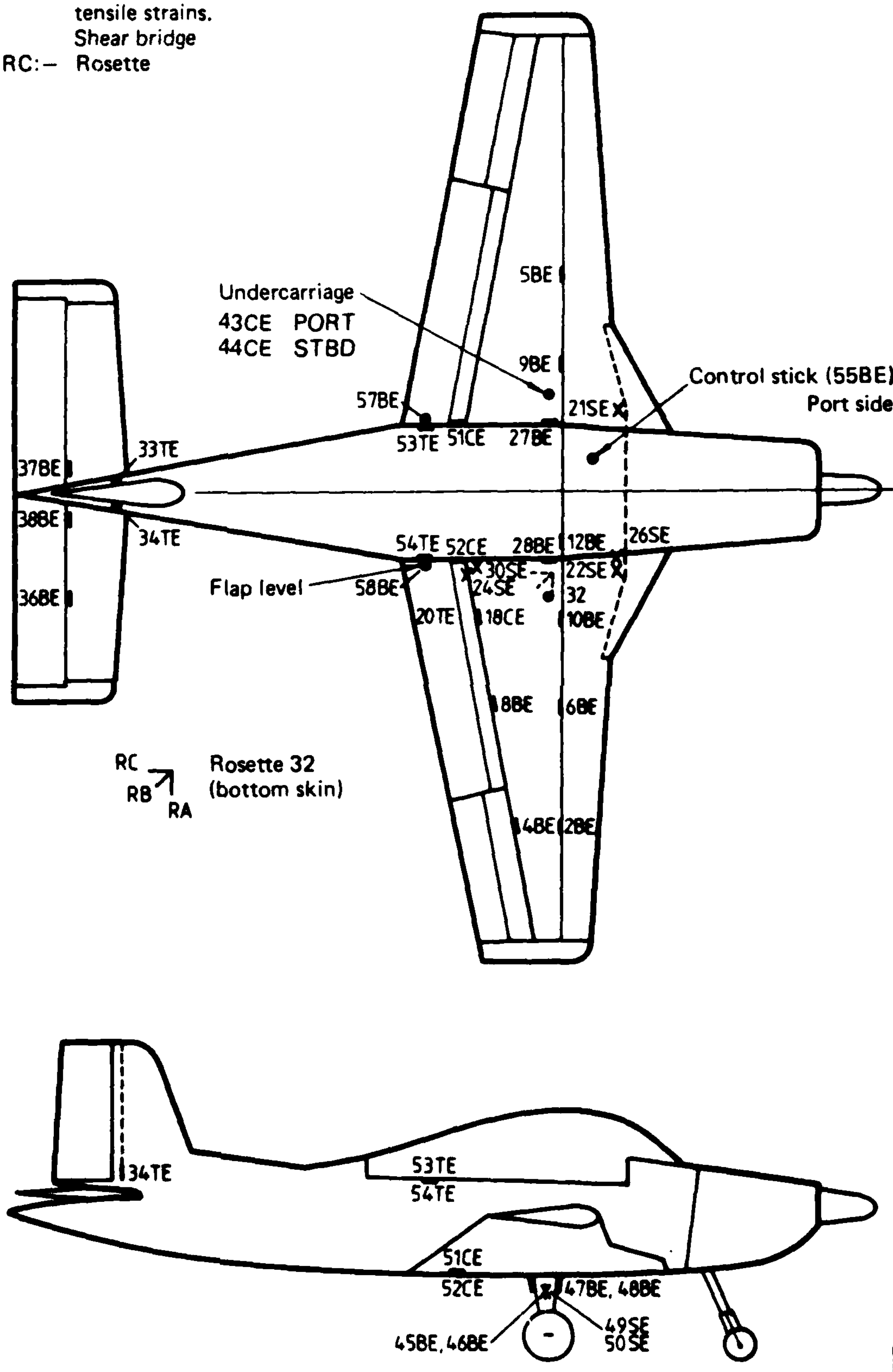


FIG. 1 CT–4A AIRTRAINER – STRAIN GAUGE POSITIONS ON FLIGHT TEST AIRCRAFT

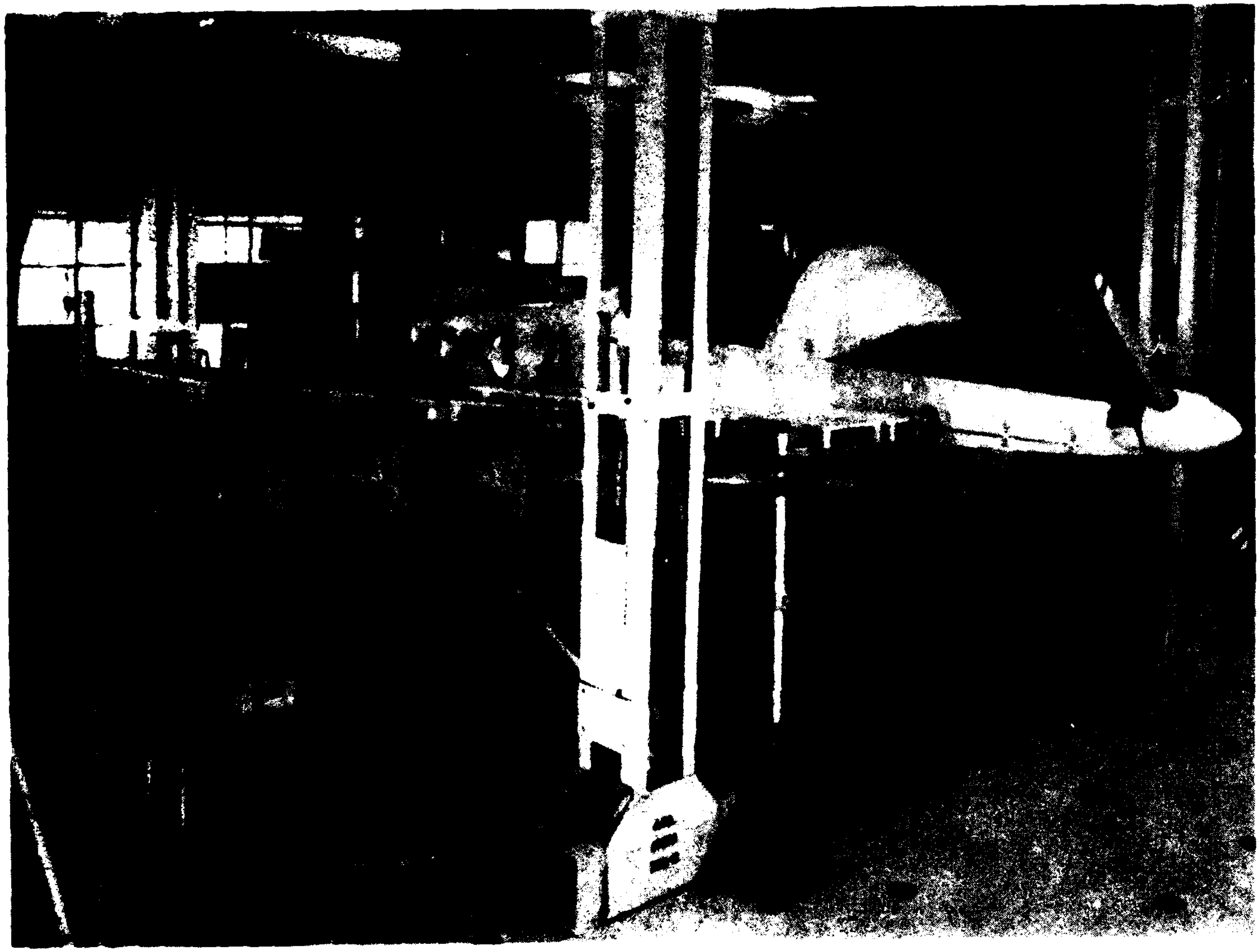


FIG. 2 WING BENDING CALIBRATION (1977)

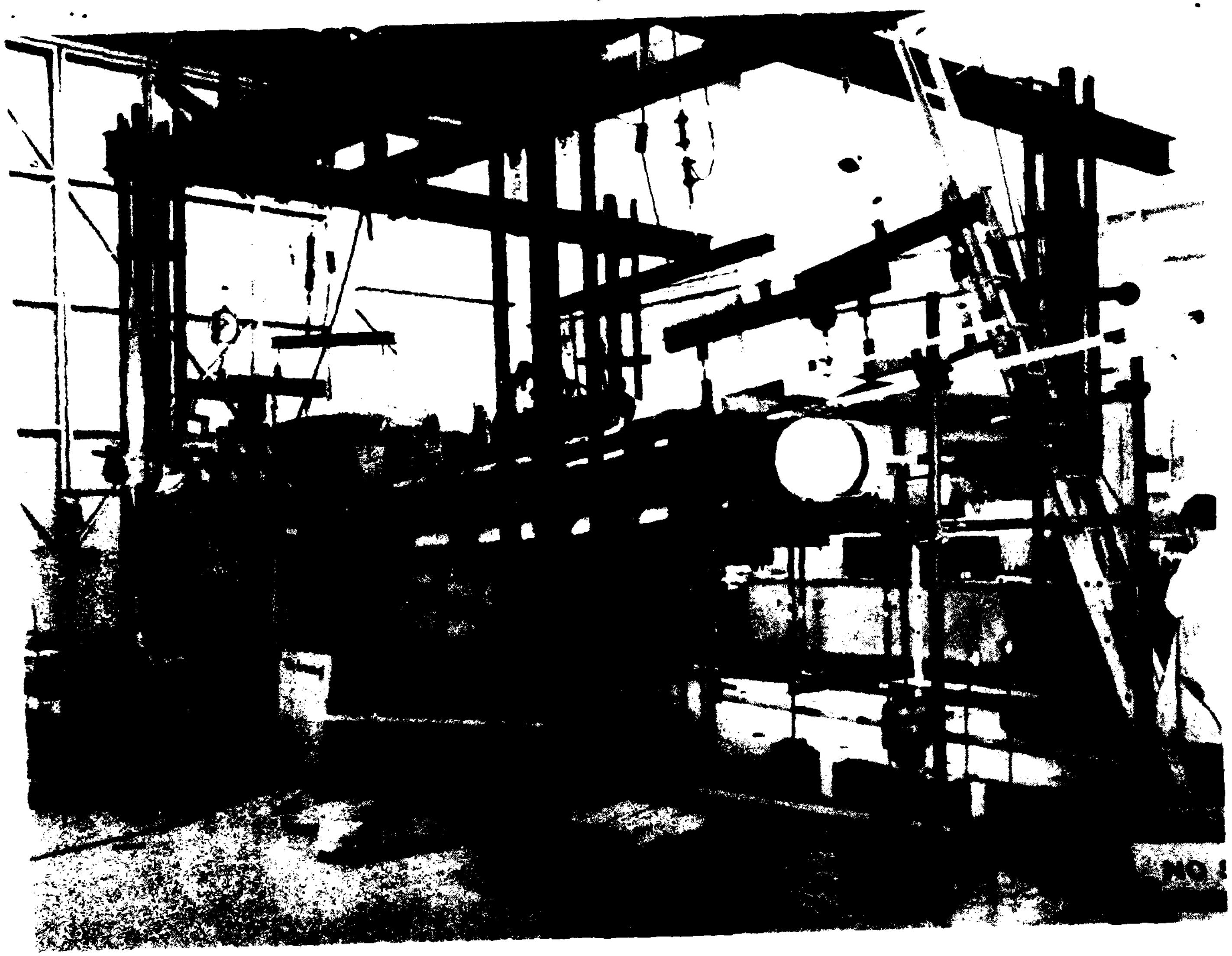
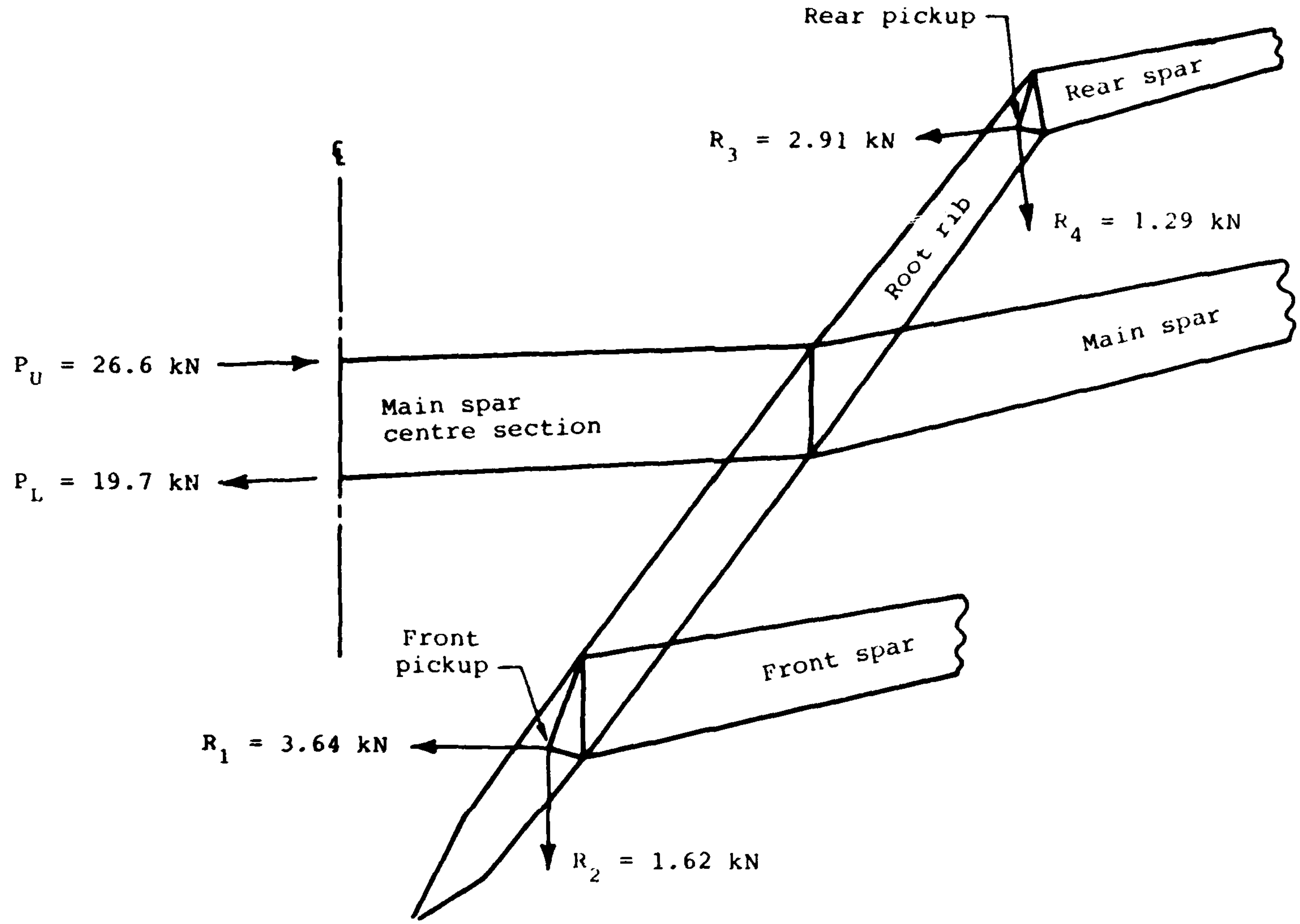


FIG. 3 WING TORQUE CASE 2 LOADING (1980)



Applied lift 2.92 kN per side

FIG. 4 FINITE ELEMENT METHOD ANALYSIS - EFFECT OF LOW SLUNG WING PICKUPS

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16. Abstract

A CT-4A flight test aircraft has been strain-gauged and subjected to various ground calibration loadings including wing bending, wing torque, tailplane bending, and fin bending.
Results of regression analyses on the strain, load data are presented and compared with previous calibrations.

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